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ORIGINAL PAPER

Condition assessment of pine swamp forest *Vaccinio uliginosi-Pinetum* habitat in the Polesie National Park

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ABSTRACT

Pine marshy forests *Vaccinio uliginosi-Pinetum* Kleist 1929 are associations included in Natura 2000 areas. They are at the highest risk of dismemberment due to global climate change. The study assessed the possibility of regeneration and genetic variability of Scots pine in a marshy forest habitat. The research was carried out in the Polesie National Park on the Durne Bagno and Lake Moszne peatbog. In the examined locations the phytocenosis of pine marshy forest was characterized. Subsequently the density of pine seedlings was estimated and their height measured. The genetic variability of the pine regeneration was estimated using the ISSR technique.
Based on the research results, it was concluded that the regeneration potential of pine was low. On average, 200 regeneration plants were inventoried per hectare, and their average height was 26.34 cm. Significantly more pine regeneration was recorded (123 plants) in Lake Moszne, with an average height of 6.99 cm. By contrast, only 36 pine trees were inventoried in Durne Bagno, but their height was 45.69 cm. Scots pine genetic variability was similar in both locations. The percentage of polymorphic loci was 74.24. The average number of alleles per locus reached 1.685 and the effective number of alleles per locus was 1.405. The expected heterozygosity and Shannon index were 0.239 and 0.362, respectively. The phytocenosis was scarce, but characteristic of the V*accinio uliginosi-Pinetum* habitat. In total, 17 species were inventoried, of which 11 occurred in both locations. Light, humidity and habitat fertility indices were characteristic of this type of habitat and amounted to 6.98, 7.70 and 1.53, respectively. No relationship between undergrowth vegetation and the Scots pine regeneration was found. A negative effect of bog blueberry *Vaccinium uliginosum* L. on the number of pine regeneration was demonstrated only in the Durne Bagno location. Shading of the tree and shrub layer did not suppress the growth of Scots pine regeneration or undergrowth vegetation.
Based on the study results, we concluded that the current state of preservation of pine marshy forests in the Polesie National Park was satisfactory. The presence of pine in the shrub layer allowed to conclude that the survival of seedlings in pine marshy forests was possible and could lead to their transition to the next developmental phases. However, as a result of the ongoing climate change and those predicted in the near future, we recommend constant monitoring of the habitat in order to maintain its sustainability.

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KEY WORDS

conservation, genetic variability, ISSR markers, natural regeneration, *Pinus sylvestris*, *Vaccinio uliginosi-Pinetum*

Introduction

Since the mid-1980s, there has been a marked change in the heat balance in Europe, which demonstrates climate warming caused by the increasing concentration of carbon dioxide in the atmosphere (Mearns *et al*., 1984; Goddess *et al*., 1990). According to predictions, further increases in carbon dioxide emissions in the coming century will result in higher air temperatures, lack of continuous and uniform precipitation in the summer, and the occurrence of heavy precipitation mainly in the cold season. As a result, the stability of forest ecosystems will be significantly reduced (Paluch, 2006; Savva *et al*., 2006; Lorenc, 2016). Modification or disappearance of many habitats can be expected along with the observed climate changes (Sikora, 2022).

Pine marshy forest *Vaccinio uliginosi-Pinetum* Kleist 1929 is one of the endangered ecosystems. It is a natural habitat covered by the Natura 2000 network, widespread in Central and Eastern Europe. It is most common in forests of the boreal zone of the continent (Ellenberg, 1978). The actual area of the *Vaccinio uliginosi-Pinetum* complex in Poland is 250 km^2 (Matuszkiewicz, 2001). It occurs in moist areas with high levels of stagnant groundwater derived from precipitation. According to the projected climate changes, pine marshy forest will therefore be increasingly at risk of disintegration as a result of progressing drainage (Paluch, 2006; Savva *et al*., 2006; Socha, 2008; EEA, 2010).

Climate change necessitates the need to conduct research on the conservation status of endangered habitats, including pine marshy forest, and determine the succession processes occurring there (Pfadenhauer and Grootjans, 1999; Czerepko, 2011). The natural regeneration capacity of Scots pine *Pinus sylvestris* L. in this habitat and the parameters of its genetic variability should also be assessed. Effective pine regeneration is essential for the sustainability of the habitat. On the other hand, genetic variability determines the adaptive potential of a species in the changing climate conditions (Gregorius, 1989; Hattemer *et al*., 1993). Nevertheless, to date, little attention has been paid to the simultaneous assessment of the regenerative potential and genetic variability of Scots pine in marshy forests (Czerepko, 2011; Masternak *et al*., 2022).

The aim of the study was to determine the regeneration potential and stability of the marshy forest habitat in the Polesie National Park. The study evaluated the species composition and herbaceous vegetation cover of the forest floor, *i.e.*, the fastest indication of changes in the habitat. Subsequently, the regeneration potential of Scots pine and its genetic variability were determined using the ISSR (Inter-Simple Sequence Repeat) technique. The following hypotheses regarding the current state of the marshy forest habitat have been assumed in the work: 1) undergrowth vegetation is typical of marshy forest and does not inhibit the growth of Scots pine regenerations; 2) regeneration density is similar to that of pine trees in other forest coniferous habitats; 3) genetic variability of pine trees is typical of this species. Our research answers the question about the current state and sustainability of the marshy pine forest habitat.

Materials and Methods

Study area. The research was carried out in the Polesie National Park, which was established in 1990, mainly to protect acquatic and peatland ecosystems. However, interest in the area existed much earlier. The 'Durne Bagno' reserve was established in 1966, and in subsequent years other reserves were created, including 'Lake Moszne'. These areas were included first in the Polesie Landscape Park (1983) and then in the Polesie National Park, whose total area currently amounts to 96.47 km^2.

The analyzes were carried out on *Vaccinio uliginosi-Pinetum* marshy forest on the Lake Moszne and Durne Bagno raised bog. In the analyzed patches of the *Vaccinio uliginosi-Pinetum* association, the stand was formed of Scots pine of IV age class (72 years in Lake Moszne and 76 years in Durne Bagno). This is the first such complex inventory in Polesie National Park.

Field data collection and analysis. At each site, 10 circular plots with a radius of 3.50 m were designated. The circular plots covered the entire area of the studied marshy forests. There were newly assemble and marked in the field. Pine seedlings were counted on the designated areas and their height was measured with an accuracy of 0.5 cm. They were classified into the following ranges: seedlings up to 20 cm (younger seeding), seedlings from 21 to 50 cm (older seeding) and saplings above 51 cm (undergrowth).

Phytosociological record were taken using the method of Braun-Blanquet (1964) in order to characterize the marshy forest phytocenosis in each test plot. There were made in July during the full growing season, when all species characteristic of this habitat are visible in the pine marshy forests. The nomenclature of vascular plants was adopted after Mirek *et al.* (2002), and bryophytes after Ochyra *et al.* (2003). Ecological indicators, developed for Central Europe by Ellenberg (1978), were used to determine the ecological spectrum of vascular plant species and habitat conditions. For this purpose, quantification degrees of Braun-Blanquet (1964) were transformed into average cover-abundance according to the scale provided by (van der Maarei, 1993). The following indices were analyzed: light (L), humidity (F) and trophism (fertility) of the habitat (N). The values of ecological indices were calculated for each plot, taking into account the occurrence of species and the percentage of area covered by these species, according to the formula described in the study of Gmyz and Skrzyszewski (2010):

$$ELW_{(L,F,N)} = \frac{\sum(ELW_{(L,F,N)} \cdot SP)}{\sum SP}$$

where:

SP – cover-abundance expressed on the Braun-Blanquet scale

The light index (L) is shown on a scale of 9, where 1 means full light plants and 9 means full shade plants. The humidity index (F) is determined on a 12-point scale, where 1 means plants of very dry habitats, 9 – wet habitats, and 12 – plants occurring in marsh habitats. The trophism index (N) is presented on a 9-point scale, with 1 indicating plants growing in very poor habitats and 9 in fertile ones (Matuszkiewicz, 2006).

Laboratory data collection and analysis. Needles from three pine regenerations was collected from each sample plot, and was used for genetic analyses. In total, genetic variation of 60 pines was analyzed (30 from Durne Bagno and 30 from Lake Moszne). Analysis of 131 intermicrosatellite loci (ISSR) was performed, generated in total by 15 primers with the following sequences: (GT)8C; (AC)8G; (GA)7YG; (GA)8C; (CA)8GC; (TC)8G; (AG)8YT; (TC)8CC; (AC)8T; (CA)8A; (TC)9A; (AC)9G; (ATG)6T; (AC)8T; (AC)8YG, where Y – indicates T or C. Genomic DNA extraction was performed according to the methodology described by Rogers and Bendich (1988). After the standard analysis, the basic parameters of genetic variability were determined: percentage of polymorphic loci (P%), mean number of alleles per locus (Na) and effective number of alleles per locus (Ne) (Bergmann and Gregorius, 1979), expected heterozygosity (He) (Nei and Roychoudhury, 1974), as well as the Shannon index (Brown and Weir, 1983). The genetic distance between the individuals studied (Nei, 1972) was calculated, and principal coordinate analysis (PCoA) was performed on its basis. Calculations were made using the GeneAlex software ver. 6.5 (Peakall and Smouse, 2006).

Statistical data analysis. The consistency of the distribution of the studied characteristics with the normal distribution was checked using the Shapiro-Wilk test. Differences in the abundance and height of regeneration on both sites were determined using Student's *t*-test. The U Mann--Whitney test was used to compare the degree of surface cover by herbaceous vegetation on both sites: Durne Bagno and Lake Moszne. In order to determine the microhabitat conditions conducive to the natural regeneration of Scots pine, the Spearman correlation coefficients were estimated between the density of the seedlings and cover of the study area by the layer of trees, shrubs, herbaceous plants and mosses, as well as by individual species occurring in the herbaceous vegetation layer. The relationship between the number of seedlings and the values of ecological indicators, which indirectly show the prevailing light and soil conditions at the site, was also assessed. Calculations were made using the statistical package Statistica ver. 13.1 (StatSoft Inc., 2016).

Results

In the Lake Moszne pine marshy forest, the number of seedlings was over three times higher (123 individuals) compared to that found on the experimental plots established in Durne Bagno (36 individuals). The difference in the abundance was statistically significant (t=2.409; p=0.027). In addition to abundance, pine regeneration from the two sites also differed in height (t=8.958; p<0.001). In the Lake Moszne, the average height of the pine regeneration was 6.99 cm, and it was classified entirely as a younger seedings. On the other hand, in Durne Bagno, the presence of 13 younger seedings, 12 older seedings and 11 undergrowth was recorded, and the average height of the regeneration was 45.69 cm.

On both sites, the stand was entirely composed of Scots pine *Pinus sylvestris*. The tree cover was significantly higher in Lake Moszne than in Durne Bagno. Scots pine, downy birch *Betula pubescens* Ehrh., pedunculate oak *Quercus robur* L. and alder buckthorn *Frangula alnus* Mill. were found in the shrub layer. However, the area covered by the shrub layer did not differ between the analyzed sites Durne Bagno and Lake Moszne (Table 1).

The average surface cover by the layer of herbaceous plants and mosses was significantly higher in Durne Bagno than in Lake Moszne (Table 1). In total, 17 species of herbaceous plants and mosses were recorded, of which 11 species occurred in both sites (Table 2). *Pleurozium schreberi* (Willd. ex Brid.) Mitt., *Dicranum polysetum* (Sw.), *Sphagnum rubellum* (Wils.), *Sphagnum magellanicum* (Brid.) and *Sphagnum cuspidatum (*Ehrh. ex Hoffm.) were also found in pine marshy forest located at Lake Moszne, while *Vaccinium vitis-idaea* (L.) and *Andromeda polifolia* (L.) in Durne Bagno.

Table 1.
Percentage of area coverage and differences between objects determined by U-Mann-Whitney test

Layer	Percentage of area coverage		p
	Lake Moszne	Durne Bagno	
Trees	63	53	0.002**
Shrubs	10	7	0.736^{ns}
Herbaceous plants	69	82	0.077^{ns}
Mosses	75	89	0.043*

significant at the level: *0.05, **0.01, ^{ns}not significant

The light index (L) in both locations showed the presence of plants of moderate light, while the trophism index (N) indicated the presence of plants characteristic of poor habitats. With respect to humidity index (F), moist habitat vegetation was present in the area of the Lake Moszne pine marshy forest, and of wet habitats in Durne Bagno (Table 3).

Genetic analysis of pines growing in Lake Moszne showed the presence of 125 alleles, of which 7 were classified as private. There were 124 alleles in the Durne Bagno pine regeneration, of which 6 were private alleles. Pines growing on both sites were characterized by very similar genetic variability parameters. More than 74% loci were polymorphic. The difference between the mean and effective number of alleles per locus was 0.28. This indicated that not the entire allele pool was passed on to the progeny. The expected heterozygosity reached an average value of 0.239, and the Shannon index – 0.262 (Table 3).

The genetic distance between the regenerations in both sites was 0.056. On its basis, the pines were divided into separate assemblages. This division, did not overlap with site location (Fig. 1).

In the area of Durne Bagno, the influence of individual layers and species of herbaceous vegetation and mosses on the number of pine seedlings was not observed. The correlation coefficient between the trees and shrubs layers and the number of seedlings and undergrowth was low and statistically insignificant. This indicates that the shading did not suppress the development of pine regeneration. No significant correlation between the layer of herbaceous plants and mosses and the number of pine regeneration was obtained. Only in the area of the pine

Table 2.
Percentage of area coverage by individual species and differences between objects determined by U-Mann-Whitney test

Species		Percentage of area coverage		p
		Durne Bagno	Lake Moszne	
Herbaceous plants	*Ledum palustre*	60.00	38.50	0.026*
	Vaccinium uliginosum	7.75	27.50	0.001**
	Vaccinium myrtillus	0.03	21.25	
	Eriophorum vaginatum	29.50	13.50	0.014*
	Oxycoccus palustris	25.76	4.00	0.001**
	Calluna vulgaris	0.06	1.04	0.677^{ns}
Mosses	*Sphagnum magellanicum*	52.50	43.00	0.212^{ns}
	Sphagnum fuscum	5.52	0.52	0.623^{ns}
	Polytrichum strictum	2.02	2.31	0.909^{ns}
	Sphagnum fallax	23.00	12.75	0.104^{ns}
	Aulacomium palustre	0.03	6.01	0.008**

significant at the level: *0.05, **0.001, ^{ns}not significant

Table 3.
Parameters of genetic variability and ecological indicator numbers of Scots pine in Polesie National Park

Area	Parameters of genetic variability					Parameters of ecological indicator numbers		
	P%	N_a	N_e	I	H_e	L	F	N
Lake Moszne	78.03	1.727	1.423	0.381	0.251	6.83	7.39	1.72
Durne Bagno	70.45	1.644	1.387	0.343	0.227	7.14	8.02	1.35
Mean	74.24	1.685	1.405	0.362	0.239	6.98	7.70	1.53

P% – percentages of polymorphic loci, N_a – average number of alleles at the locus, N_e – effective number of alleles at the locus, I – Shannon index, H_e – expected heterozygosity, L – light indicator, F – humidity indicator, N – trophic indicator

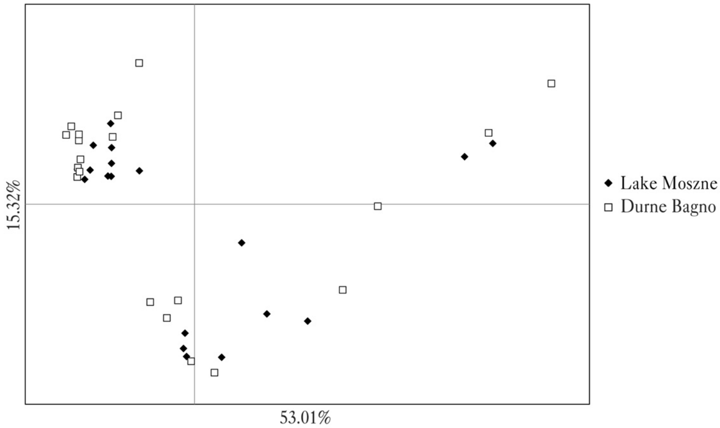

Fig. 1.
Results of PCoA analysis based on genetic distance

marshy forest located at Lake Moszne, a significant effect of *Vaccinium uliginosum*, on the number of appearing pine seedlings was demonstrated. The correlation coefficient was –0.801 and was significant at the level of α=0.01.

Discussion

Abundance and genetic variability of natural pine regeneration. The density of the young generation of Scots pine in pine marshy forests was very low and averaged 0.2 plants/m^2, *i.e.*, 200 plants/ha. This is a much lower value than the one allowed in Poland when recognizing cultivation from natural regeneration In managed forests, crop from natural regeneration are recognized if the number of seedlings is not less than 20 plants/m^2 (Order, 2005). The density obtained by us in pine marshy forests is also lower than that recommended for artificial plantings (Modrý *et al.*, 2004; ZHL, 2012). A much higher number of pine regenerations was also recorded by Dobrowolska (2010) in the mixed coniferous forest habitat (9-45 thousand plants/ha) and in the fresh mixed forest habitat (8-59 thousand plants/ha). Zawadzka and Słupska (2022), analyzing pine regeneration under the canopy, also obtained a higher value of 7 820 plants/ha. A similar density was found in swamp forests in eastern Poland (Masternak *et al.*, 2022). This indicated that the processes of marshy forest regeneration were slow. Shading, however, did not suppress seedling growth, as no significant effect of the tree and shrub layer was found on the number of pine seedlings. Moreover, the presence of pine in the shrub layer with an average cover of 7 to 10% allowed to conclude that the survival of seedlings in pine marshy forests was possible and could lead to their transition to the next developmental stages.

The natural regeneration of Scots pine was genetically variable, as 74.24% of the loci tested were polymorphic. This represented an average value for Scots pine, as both lower (P%=42) (Hui-yu *et al.*, 2005) and higher (P%=95) (Vidyakin *et al.*, 2015) percentage of polymorphic loci for this species, genotyped using ISSR markers, could be found in the literature. The Shannon index was 0.362, which corresponded to an intermediate value for Scots pine. For example, Vidyakin *et al.* (2015) obtained the Shannon index value of 0.6907 for Scots pine from north--eastern Russia. Masternak *et al.* (2022) for pine from eastern Poland obtained a value of the similar Shannon index of 0.301. Hui-yu *et al.* (2005) obtained a much lower value of 0.158 for the pine population from China. Using the PCoA technique, the studied pine regenerations were divided into two clusters. They did not overlap with the presence of pine in individual sites.

The natural regeneration of pine in the analyzed patches of the Polesie National Park was surrounded by stands of a similar age, which could indicate a common origin.

Noteworthy is the presence of private alleles in both populations, accounting for slightly more than 5% of identified alleles. In addition to rare alleles, they enrich the genetic diversity of the population. This in turn determines the adaptive potential of trees (Gregorius, 1989; Hattemer *et al.*,1993). According to Konecka *et al.* (2019), the presence of private alleles could be associated with selection pressure and adaptation to external conditions. This finding opposed the results of studies by other authors indicating that rare and private alleles occur most frequently in phenotypically weaker individuals (Bergmann and Scholz, 1987; Bush and Smouse, 1991; Chen *et al.*, 2001), which are eliminated due to high mortality in the first stages of stand development (Barrett and Kohn, 1991). In order to verify this contradiction, it would be necessary in the future to compare the genetic variability of pine regeneration to that in the next generation, and currently also in the growing parental generation (old stands).

FOREST FLOOR VEGETATION. Vegetation is an element of the ecosystem that responds best to changes in some of its components (Roo-Zielińska and Solon, 1991). Knowledge of the vegetation cover specific to a given habitat, its spatial diversity, and quantitative and qualitative species characteristics allows to determine the variability and processes occurring in the environment (Roo-Zielińska, 2004). Vascular plants are most often used to determine the condition and changes in the environment (Ellenberg *et al.*, 1991; van der Maarei, 1993; Zarzycki, 2002). This method allowed to determine the occurrence of species characteristic of the complex of marshy forests located in the Polesie National Park, *e.g.*, *Ledum palustre* (L.) and *Vaccinium uliginosum*. There were also peat bog species that belonged to indicators of a good conservation status of marshy forest, *e.g. Sphagnum* spp., *Oxycoccus palustris* (L.), *Andromeda polifolia*, and *Eriophorum vaginatum* (L.). No non-forest or invasive species were recorded for this type of habitat.

Marshy forest communities are not rich in terms of species composition. According to Matuszkiewicz (2002), an average of about 20 species occurred in them, and the number of species recorded within the whole assemblage was approx. 80. A total of 17 species have been identified in marshy forests located in the Polesie National Park. Czerepko (2011), analyzing marshy forest patches in the Augustów Forest in the Kurjańskie Bagno reserve, showed the presence of 45 species, and Sokołowski (1969) identified 41 species 45 years earlier. The number of species recorded by us was therefore low, however, as indicated by Halpern and Spies (1995) and Gilliam and Roberts (2003), this number might increase with stand development.

The average light index reached a value of 6.98 and was comparable to that characteristic of the *Vaccinio uliginosi-Pinetum* habitat. Roo-Zielińska (2004) reported that the average light index for marshy forests in Poland was 5.7, with over 80% of forests having an index between 6 and 7. The average trophism and humidity index calculated for both sites was 7.70 and 1.53, respectively, indicating a poor and wet habitat. This allowed to conclude that the condition of the pine marshy forest habitat in Polesie National Park was appropriate and it could be assumed that the regeneration of the vegetation located there would continue spontaneously.

RELATIONSHIP BETWEEN PINE REGENERATION AND HERBACEOUS VEGETATION COVER. Natural regeneration of pine is favored by moss or moss-*Vaccinium* cover, which is characteristic of poor boreal habitats (Hafeman, 2005; Gmyz and Skrzyszewski, 2010). Among the herbaceous plants, *Dicranum scoparium* (L.), *Leucobryum glaucum* (Hedw.) (Zerbe *et al.*, 2007), as well as *Avenella flexuosa* (L.) (Lust *et al.*, 2000) have a positive effect on the regeneration of pine trees. Many studies have also indicated the existence of herbaceous vegetation that is competitive for the emergence of natural regeneration of Scots pine. Depending on the habitat, these are, *e.g.*, *Vaccinium* *myrtillus* (L.) (Gmyz and Skrzyszewski, 2010) or tall grasses such as *Calamagrostis* spp. and *Deschampsia caespitosa* (L.) (Karlsson and Nilsson, 2005). In our study, the presence of *Vaccinium uliginosum* had a negative impact on regeneration, but only in the Durne Bagno pine marshy forest. It covered 60% of the area of the analyzed site.

More important than the impact of individual species seems to be the total density of herbaceous plants, which has a negative effect on the abundance of natural regeneration of Scots pine (Masternak *et al.*, 2022). However, in this study, we did not demonstrate a relationship between the number of seedlings and surface cover by the layer of herbaceous plants and mosses. It was also shown that the tree and shrub layer did not inhibit the light access into the stand and did not limit the growth and development of pine seedlings. This indicated that the adequate amount of light, necessary for the proper growth of the species, reached under the canopy stand. One-year-old pine seedlings need a minimum of 10% light to survive (Obmiński, 1970). Older seedlings and saplings require 35% full light for proper development (Hale *et al.*, 2009). Some authors have suggested that Scots pine seedlings are unable to survive under the tree stand canopy (Coban *et al.*, 2016). However, Zawadzka and Słupska (2022) refuted this view by showing that pine could successfully regenerate under the canopy of maternal trees. In addition, the presence of pine in the shrub layer with an average cover of 7% in Durne Bagno and 10% in Lake Moszne, as shown in the present study, allows to conclude that the transition of pine from the seedling phase to subsequent developmental stages in marshy forests is possible.

Conclusions

On the basis of the performed experiments, the following can be concluded:

- Condition of pine marshy forests in the Polesie National Park was appropriate for this type, wet habitats. Despite the relatively low number of species of herbaceous plants, the presence of non-forest or invasive species was not recorded. Herbaceous plants and mosses was typical of this habitat and the values of ecological indices allowed to conclude that regeneration processes of undergrowth plants occurred spontaneously.
- Pine regeneration abundance was very low, which may raise concerns about the continued sustainability of the marshy forest. Nevertheless, shading did not suppress the growth of undergrowth vegetation, and the presence of pine in the shrub layer allowed to conclude that survival of seedlings in pine marshy forests was possible and could lead to their transition to the next developmental stages.
- Genetic variability of Scots pine was similar to that of other provenances of this species. This proved the potentially good adaptability of pine in this habitat.

The future regeneration potential of the pine and conservation status of the pine marshy forest must be monitored over a period of several years. for the further monitoring, it will be possible to use the currently established research areas in the field. If negative changes of this ecosystem are observed, a quick reaction of foresters will be possible, to preserve it.

Authors' contributions

Conceptualization – K.M, D.U.; Data curation – K.M., D.U.; Formal analysis – K.P.; Methodology – K.M, D.U.; Project administration – K.M.; Software – K.M.; Supervision – K.M.; Visualization – K.M.; Writing-original draft – K.M.; Writing-review and editing – K.M., D.U.

Conflicts of interest

The authors declare, that they have no conflict of interest.

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STRESZCZENIE

Ocena stanu siedliska sosnowego boru bagiennego *Vaccinio uliginosi-Pinetum* w Poleskim Parku Narodowym

Sosnowe bory bagienne *Vaccinio uliginosi-Pinetum* Kleist 1929 wchodzą w skład siedlisk Natura 2000. W ostatnich latach stały się w dużym stopniu narażone na rozpad wskutek globalnych zmian klimatu. W pracy oceniono obecny stan siedliska boru bagiennego, a w szczególności możliwość odnawiania się i zmienność genetyczną sosny zwyczajnej. Badania wykonano w Poleskim Parku Narodowym, który został założony przede wszystkim w celu ochrony ekosystemów wodno-torfowiskowych. Analizami objęto torfowiska Durne Bagno oraz Jezioro Moszne. Scharakteryzowano fitocenozę boru bagiennego oraz wskaźniki ekologiczne: świetlny, wilgotności i żyzności siedliska. Oszacowano zagęszczenie nalotów i podrostów sosny oraz zmierzono ich wysokość. Zmienność genetyczną odnowienia oszacowano przy pomocy techniki ISSR (polimorfizm sekwencji międzymikrosatelitarnych).

Na podstawie wykonanych badań stwierdzono, że potencjał regeneracyjny sosny w borach bagiennych w Poleskim Parku Narodowym jest niewielki. W przeliczeniu na 1 ha powierzchni zinwentaryzowano jedynie 200 sztuk odnowienia. Jego średnia wysokość wynosiła 26,34 cm. Na torfowisku Durne Bagno zinwentaryzowano 36 sosen, z czego 13 zaliczono do nalotu młodszego, 12 do nalotu starszego, a 11 do podrostu. Ich średnia wysokość wynosiła 45,69 cm. Z kolei na torfowisku Jezioro Moszne zanotowano trzykrotnie więcej odnowienia sosnowego (123), o średniej wysokości wynoszącej 6,99 cm. Odnowienie w całości zaliczono do nalotu młodszego. Sosny rosnące na terenie obu obiektów charakteryzowały się bardzo podobną wartością parametrów zmienności genetycznej (tab. 1). Udział polimorficznych loci wyniósł 74,24. Średnia liczba alleli w locus osiągnęła wartość 1,685, a efektywna liczba alleli w locus 1,405. Heterozygotyczność oczekiwana i indeks Shannona wyniosły odpowiednio 0,239 oraz 0,362. W obu obiektach zanotowano obecność alleli prywatnych. Dystans genetyczny pomiędzy odnowieniami na terenie obu obiektów wyniósł 0,056. Na jego podstawie sosny zostały podzielone na odrębne skupienia. Podział ten nie pokrywa się z przynależnością do obiektu (ryc. 1).

W obu lokalizacjach drzewostan budowała w całości sosna zwyczajna. Wśród warstwy krzewów występowały sosna zwyczajna, brzoza omszona, dąb szypułkowy oraz kruszyna pospolita. Pokrycie powierzchni przez warstwę drzew było istotnie wyższe na torfowisku Jezioro Moszne niż Durne Bagno, natomiast w warstwie krzewów nie różniło się pomiędzy analizowanymi obiektami (tab. 2). Fitocenoza borów bagiennych była nieliczna, ale charakterystyczna dla siedliska *Vaccinio uliginosi-Pinetum*. Łącznie zinwentaryzowano 17 gatunków, z czego 11 występowało w obu lokalizacjach (tab. 3). Wskaźnik świetlny (L), wilgotności (F) oraz żyzności siedliska (N) były charakterystyczne dla siedlisk borowych i wyniosły odpowiednio 6,98, 7,70 oraz 1,53 (tab. 1). Nie wykazano związku pomiędzy roślinnością runa a pojawiającym się odnowieniem sosny zwyczajnej. Jedynie w lokalizacji Durne Bagno wykazano ujemny wpływ borówki bagiennej na liczebność odnowień sosnowych. Ocienienie zarówno warstwy drzew, jak i krzewów nie tłumiło wzrostu odnowień sosny zwyczajnej ani roślinności runa.

Na podstawie uzyskanych wyników można stwierdzić, że obecny stan zachowania borów bagiennych w Poleskim Parku Narodowym jest stabilny. Typowa dla tego siedliska roślinność runa oraz wartości wskaźników ekologicznych pozwalają wnioskować o zachodzących tam spontanicznych procesach regeneracji. Liczebność odnowienia sosnowego była niewielka, co może budzić

obawy dotyczące dalszej trwałości boru bagiennego. Niemniej jednak ocienienie nie tłumiło wzrostu odnowień, a obecność sosny w warstwie krzewów pozwala wnioskować o tym, że przeżycie nalotów w borach bagiennych jest możliwe i może prowadzić do ich przejścia w kolejne fazy rozwojowe. Zmienność genetyczna sosny zwyczajnej była podobna do tej, jaką charakteryzują się inne proweniencje tego gatunku. Świadczy to o potencjalnie dobrej możliwości adaptacyjnej sosny na tym siedlisku. Jednak w obawie przed dalszymi przewidywanymi zmianami klimatu korzystne wydaje się stałe monitorowanie siedliska, w celu zachowania jego trwałości.